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J. RABINOW

2,933,246

READING MACHINE

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Fig. 1

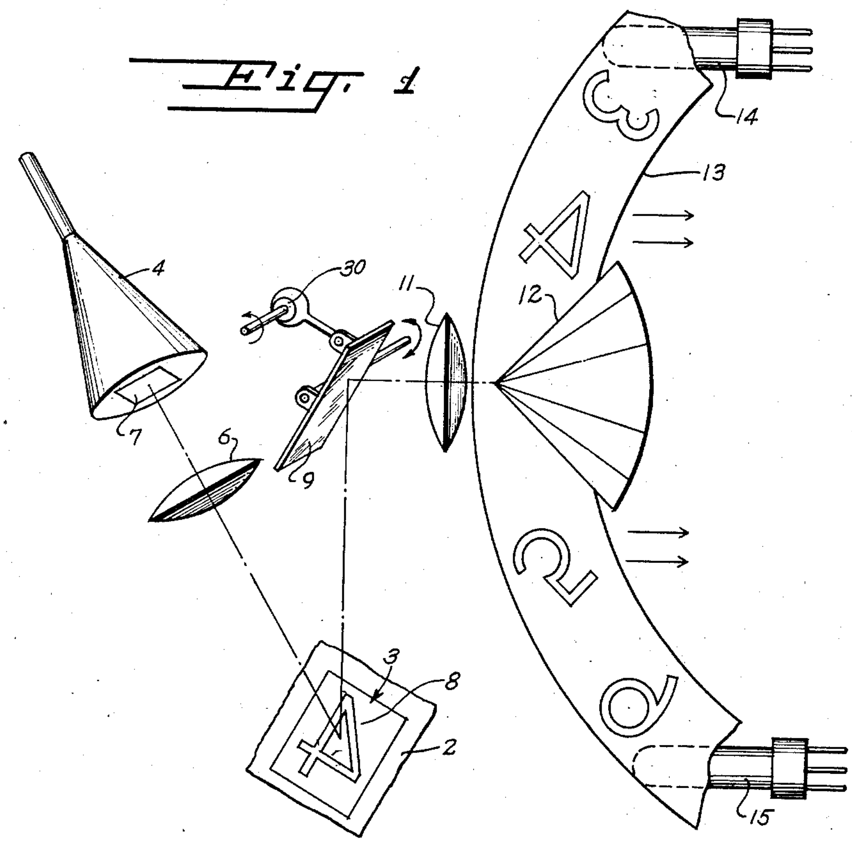
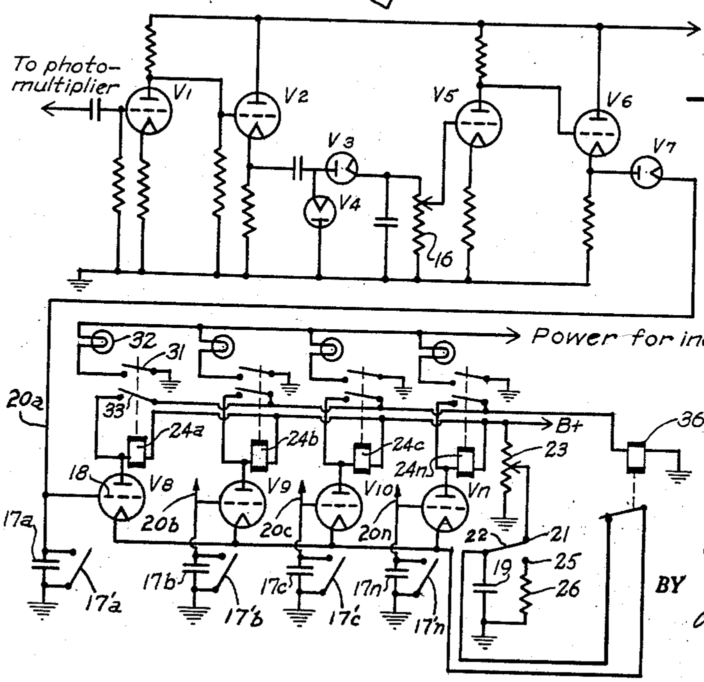


Fig. 2



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READING MACHINE

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This invention relates to the art of reading or character recognition machines. More specifically, it relates to the art of reading machines in which the internally stored characters, or memory, are optical elements, as contrasted against machines where the memorized characters or elements are in the form of "bits" of electrical information. While the main characteristics of my invention pertain to optical memory devices, it should be understood that certain features of the invention pertain to other machines as well.

The main object of my invention is to employ a "maximum match" device in recognizing characters, so that defective print, soiled paper and other defects of the material to be read should give rise to as little trouble as possible in the machine's operation.

Another object of the invention is to provide a machine that can read various fonts with simple changes in set-up.

Another object of the invention is to provide a device capable of reading characters at very high speed.

The specific nature of the invention, as well as other objects and advantages thereof, will clearly appear from a description of a preferred embodiment as shown in the accompanying drawing in which:

Fig. 1 is a schematic diagram showing the principle of a preferred arrangement of the mechanical components of my device; and

Fig. 2 shows the electrical circuit of my invention.

The characters to be read are assumed to be dark print on light paper 2. This paper can be held and positioned by any suitable means which are secondary to the main purpose of this invention. The field of interest 3 on the paper 2 is illuminated by a flying spot scanner consisting of a cathode ray tube 4 and the lens 6. The cathode ray tube produces a bright spot on its front surface, and suitable circuitry well known to the art is employed to produce a raster 7 on the face of the tube 4. As will be explained below, the raster need not be held to close tolerances as regards position, speed, or jitter of the spot. In fact, I prefer a raster that is not regular in pattern but one in which the spot criss-crosses the field on alternate field-scans. Such a raster is described, for example, in National Bureau of Standards Report No. 4108, June 1955, on "Image Processing." Mechanical scanning means may be employed in place of the flying spot scanner and one such means is shown in my report TR–128 of the Diamond Fuze Laboratories, dated November 26, 1954.

The illuminated area 8 of the paper is projected by means of mirror 9, lens 11, and multifaced mirror 12 onto a strip of film 13 that acts as the "memory" of the machine. Mirror 9 is used both for mechanical convenience of the optical system and for producing vertical displacement of the image, if desired. The lens 11 is of any suitable type, preferably of large aperture. The multisided mirror 12 is made so as to have a multiplicity of flat faces, each of which casts an image of the illuminated area 8 of the paper 2 onto a different segment of the memory film 13. The memory film consists of

masks in which the character to be recognized is transparent while the rest of the area is opaque. The masks are photographically produced, preferably by using the optical system of the particular reading machine in which it is to be employed. Although this latter is not necessary if the several machines in which a particular mask is to be used are built with sufficient precision. In any case, variations in size of the mask images can be accommodated by adjustment of the lens position and its focal length. Instead of using one continuous strip of film, separate character masks can be employed and each held in its own holder in front of its respective phototube.

Behind each of the mask characters, I locate a phototube 14, 15, etc., preferably of the photomultiplier type, although other types can be used, if desired.

The operation of the reading machine is as follows: The spot of light on the cathode ray tube face 7 is projected onto the paper 2 by lens 6. The lens is so chosen and the various parts of the machine so located that the projected spot of light on the paper is approximately equal in diameter to the width of the lines composing the characters. This is generally of the order of a few thousandths of an inch. If the spot of light is much smaller, irregularities in the lines forming the character will be exaggerated, while if much greater, definition will be reduced and small differences between similar characters will be lost. As the spot of light on the paper moves about the area 3, some of the light reflected from the paper is gathered by the lens 11 and projected onto the mask 13. Because of the multielement front surface mirror 12, a separate image of the same character is projected simultaneously onto each character of the masks.

Assume that the character "4" is placed in the scanning position as shown in Fig. 1. The scanned image of this "4" will be projected onto all of the masks. Assume, for the moment, that the location of the "4" is such that its image exactly coincides with the transparent image "4" on the fourth mask, and, of course, does not coincide with any of the other mask images.

As is well known in this art, the numeral "4" is not totally black, i.e., the lines of which it is composed do reflect a considerable amount of light.

This means that when the gray "4" is superimposed on the transparent mask, pulses of light will go through the mask as the character is scanned and produce small "spikes" of current in the photocell circuit. All of the photocells behind masks other than the character "4" will, of course, produce large spikes when a flying spot of light impinges on the mismatched areas of each mask. If the reflectance of the character is of the order of 20%, that is, the gray of the character reflects 20% as much light as the white background, the electrical output of the No. 4 photocell will be only 20% as high as the maximum spikes of the other photocells.

Each of the photocells is connected to a circuit shown in the upper portion of Fig. 2. This circuit consists of an amplifier which may be of any suitable type but in the figure shown consists of two stages having vacuum tubes V1 and V2. The output of this amplifier feeds a peak detector consisting of two diodes V3 and V4 and their associated capacitors. The output of the peak detector is adjustably by means of gain control 16 which is connected to the grid of the amplifier tube V5 which, in turn, drives the cathode-follower V6.

The cathode-follower V6 is connected to the capacitor 17 through the diode V7 as indicated by line 20*a*. This capacitor is connected to the grid 18 of the vacuum tube V8. There is one such complete circuit for each phototube. The output of each tube V7 corresponding to each photo-tube is similarly connected by lines 20*b*, 20*c*, etc., to the respective capacitors 17*b*, 17*c*, etc., which are similarly connected to the grids of the respective tubes V9, V10, etc. The recognition tubes V8, V9, V10–VN, have their cathodes connected together. These cathodes are connected to the capacitor 19 which is normally connected to a high potential voltage through the contact 21 of the switch 22 and the voltage control 23.

In each of the plate circuits of the recognition tubes there is a relay 24*a*, 24*b*, etc., the output of which can serve to light indicator lights, operate a typewriter, or perform other functions.

It will be observed that the diodes V4 and V3 polarity is such that the spikes in the phototube produce a positive voltage relative to ground across the gain control 16. The output of the amplifier V5 produces a negative voltage in its plate circuit because of this positive voltage on its grid, and the output of the cathode-follower V6 is therefore also negative. The net result of these connections is such that as large spikes appear at the output of the photocell, negative-going voltage appears at the output of each of the complete amplifiers connected to it, and the larger the amplitudes of the spikes, the more negative is this output voltage. Another way of saying this is to say that the usually positive voltage of the cathode of tube V6 with respect to ground is lowered most when mismatch occurs, and is most positive when there is a good match.

As the character "4" moves into registry with its proper mask, the output of the cathode-follower tube V6 associated with the mask No. 4 rises. This rising voltage charges the capacitor 17 through the diode V7 and continues to raise the voltage on the capacitor 17 as long as the match is improving. When the position of the character (in this case "4") begins to recede from the position of maximum match, larger pulses will be produced, the output of the peak detector V3—V4 will rise and the output of the cathode-follower V6 will fall. Because of the one-way action of the diode V7, the output capacitor 17 will retain its best match voltage for a considerable length of time, if desired, for hours. After each character is read, the condensers 17*a*–17*n* are discharged by any suitable means, conventionally shown as switches 17'*a*–17'*n*, which are preferably closed simultaneously, either manually or by any conventional control mechanism. Prior to this, the indicator lamp, which may still register the last preceding character which was read, is extinguished in any suitable manner, e.g., by opening the power circuit which supplies it. A suitable timing and control sequence for this is shown in Fig. 13 of the TR-128 report previously referred to. It will, of course, be understood that the indicator lamps are shown merely by way of illustration and example, and that in practice a printing mechanism would often be used instead of, or in addition to, the display lamps.

It will be seen, therefore, that when a character has passed its optimum match with its mask, all of the output capacitors 17*a*, 17*b*, 17*c*, etc. will have various charges on them. If the circuit is now so operated as to determine which of the capacitors has the highest charge, the character would be recognized.

This is done as follows:

As stated earlier, each of the capacitors 17*a*, 17*b*–17N, is connected to the grid of a vacuum tube V8, V9 V10, etc., in a plate circuit of which is relay 24*a*–24N. The cathodes of all these vacuum tubes are tied in parallel and are normally held at a high positive potential so that none of these recognition tubes is conductive. If the voltage on the cathodes of the recognition tubes is now made to decrease at some definite rate, it will be seen that the tube with the most positive grid voltage will be the first to conduct, thus indicating which character is matched best. In order to provide for the decreasing voltage on the cathodes, I connect the capacitor 19 to a suitable positive potential as shown in Fig. 2, and I provide a switch 21 with contact 25 by means of which this capacitor can be discharged through resistor 26. In order to keep this description simple, I chose to operate this switch manually. In actual practice, the operation of this switch 21 is intimately connected with the general problem of character positioning and will not be described in detail.

There is a large art covering the positioning of the characters in a reading machine. The paper can be moved under the reading station in a direction parallel to the line of characters either intermittently or continuously. If the spacing of the characters is known, as for instance is the case in characters printed on business punch cards, the problem of horizontal positioning is relatively easy. It is only necessary to provide a positioning means like that of a platen of a typewriter so that the characters will appear approximately in the correct position in the reading machine. It shall be further assumed that the vertical position of the characters is also fairly well defined so that only slight vertical motion of the characters is necessary for best matching. Such small motion can be obtained by changing the angle of the mirror 9 by one of several means. I show an eccentric 30 which can be driven by any suitable motor which can move the characters in a vertical direction as the eccentric revolves. Cams can be arranged to move the mirror about an axis parallel to the vertical line of the character so as to move the image of the character in a horizontal direction also. By moving the character in a zig-zag direction, both vertically and horizontally while it is being scanned, a condition of best match can be obtained, and because of the action of the diode V7 the voltage corresponding to the best match can be remembered until the recognition finally can be completed. After giving the characters sufficient time to be recognized, a relay can be used for closing switch contacts 22, 25, and initiating the discharge of the capacitor 19. As described previously, one of the recognition tubes fires first and operates its plate relay. In this case assume it will be the relay 24*a* connected to the circuit of mask No. 4. This relay performs two functions. Its contactor 31 operates light 32 or other output device indicating which character has been recognized, and its second contactor 33 acts as a locking contact for relay 24*a* which holds the indicator light on over after power supply to the vacuum tubes is cut off. This cut-off is accomplished as follows:

In case one of the characters, e.g., character "4," is recognized, its relay contacter 33 not only provides a "hold" circuit for its own coil, but also actuates the coil 36 of the lock-out relay. This relay shuts off the current of the cathodes of all the tubes V8–VN, thus preventing any other tube from firing, and limiting recognition to the first character.

It will be recognized that in a simultaneous comparison machine of the type described here, the outputs of all of the photocells and their respective amplifiers should be kept reasonably equal for equal intensities of light reflected by the paper being scanned. This can be done either manually by means of the gain controls shown, or by automatic gain controls well known to the electronic art. The only important requirement for such automatic gain control is that it is slow acting as compared to a normal match cycle.

In the first machine of this general type which is described in Technical Report TR 128 of the Diamond Ordnance Fuze Laboratories, I described a reading machine where a single photocell was used with a moving mask system. The unknown character was examined sequentially by all of the masks. The best match was then determined. In that machine provision was made to eliminate ambiguities such as occurred when an "E" matched both the "E" and "F" masks. These anti-ambiguity devices are not part of this application.

The report also shows actual means used for sequencing the operation of the machine, but these means are well known to the art and need not be detailed here.

While I show in the present embodiment a machine which recognizes characters projected simultaneously on a group of masks, the report cited above shows that it is possible to recognize the characters in sequential operation and this difference between parallel and sequential operation is not important to the main purposes of this invention.

It will be apparent that the embodiments shown are only exemplary and that various modifications can be made in construction and arrangement within the scope of my invention as defined in the appended claims.

I claim:

1. In a character recognition machine, means to compare a single character of a limited group of characters being recognized with all of a plurality of memory elements, each of said memory elements defining one of all of the possible characters of the group to be recognized, means for producing a group of separate signals as a result of the individual comparisons, the magnitude of each of said signals being an indication of the degree of match in each comparison, and means responsive to the optimum signal of the group, which indicates the closest match, to actuate a unique circuit indicative of said single character.

2. The invention according to claim 1, said first named means comprising scanning means for successively examining small discrete portions of said character.

3. The invention according to claim 1, said memory elements consisting of negative masks, said masks having transparent portions on an opaque field, said transparent portions being of sizes and shapes to match the images of the characters which are to be recognized.

4. In a reading machine, flying spot scanner means to illuminate a character being recognized, optical means to project an image of the character onto each of a plurality of masks, each of said masks designed to match each of a number of possible characters to be recognized, photosensitive means to measure the degree of match between each of all of the masks and the projected image of the said character being recognized, and means to determine the one mask most nearly matching the image of the said character.

5. The invention according to claim 4, said photosensitive means comprising means for simultaneously comparing the amounts of light produced by said matching.

6. A character recognition machines comprising means to illuminate a character to be recognized, optical means to project a plurality of images of said character onto a plurality of masks each of which bears a negative image of a possible character to be recognized, the projected image and negative image being superimposed so that if they correspond an optimum optical effect is produced, photoelectric means associated with each said mask for producing a plurality of separate electric signals, each corresponding in magnitude to the optical effect produced by the projection of said image upon one of said masks, electric circuit means for comparing all of said signals with each other and including means responsive only to the signal most nearly corresponding to said optimum optical effect to actuate a circuit associated with said signal, and means uniquely responsive to actuation of said circuit to indicate the character producing said effect.

7. The invention according to claim 6, said electric circuit means comprising a separate electric storage device associated with each electric signal circuit for storing an electrical effect corresponding to the magnitude of the received signal in each circuit, a plurality of circuit actuating devices respectively associated with said storage devices for operation by said respective devices, and means for operating only the one of said actuating devices associated with the storage device storing the electrical effect corresponding to said optimum optical effect, whereby the actuated circuit corresponds to the character recognized.

8. The invention according to claim 7, said separate electric storage devices comprising a plurality of separate condensers for respectively storing a plurality of voltages respectively corresponding to said electric signals; said selection means comprising means for applying said voltages to said plurality of signal circuits, a voltage-sensitive device in each of said signal circuits, all of said devices being operable at the same critical voltage level in a range outside of the level of said stored voltages, and means for algebraically adding the same incremental voltage to all of said devices to change the resultant voltage in a direction toward said critical voltage level, whereby the optimum-charged condenser is the first to actuate its voltage-sensitive device, and means responsive to actuation of the first-actuated said device to inhibit effective operation of the other voltage-sensitive devices, whereby only the circuit corresponding to the recognized character is actuated.

9. In a reading machine for recognizing individual ones of a set of characters, image-examining means arranged to produce signal information which is a function of an unknown character to be recognized, a plurality of memory element means each containing information defining a specific character of the set, means to compare the signal information with the information contained in each of all of said memory elements, means producing, for each comparison, a separate signal the value of which corresponds to the degree of match in each instance, means for comparing said signals, and means responsive to the optimum one of said signals, corresponding to the best match, to actuate a device indicative of the selected character.

10. The invention according to claim 9, said separate signals being electrical signals of magnitude related to the degree of match, and said signal comparison means comprising a separate storage condenser for storing a charge corresponding to each respective signal, said responsive means comprising separate electronic means connected respectively to each storage condenser.

11. The invention according to claim 10, said electronic means comprising vacuum tubes biased to cut-off, each said condenser being connected to a control grid of one of said vacuum tubes, means for simultaneously reducing the bias of all said vacuum tubes until one of said tubes fires, and means for inhibiting the firing of the other vacuum tubes.

12. In a character reading machine, means to scan a character to be recognized, photo-responsive means associated with said scanning means, image examining means including said scanning means to produce information which is a function of said character, a plurality of memory element means each storing information defining one of a set of characters to be recognized, said photo-responsive means being arranged to produce signals which are a function of the character information produced by the said scanning means, and means to compare said signals with said stored information to determine which one of all said memory elements contains the character information most closely matched to the information derived from said unknown character.

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Notice of Adverse Decisions in Interferences

In Interference No. 92,210 involving Patent No. 2,933,246, J. Rabinow, READING MACHINE, final judgment adverse to the patentee was rendered Jan. 30, 1969, as to claim 12.

[*Official Gazette October 23, 1973.*]